

REMARKS/ARGUMENTS

By this amendment, claims 1 and 14 are amended to recite that the p-type semiconductor material has a luminescent peak at about 3.357 eV. Support for this amendment may be found in the specification, paragraph [0081] and Fig. 3. Claim 27 is amended to recite that the antimony-doped p-type zinc oxide semiconductor material has a carrier mobility greater than about 100 cm²/V·s. Support for this amendment may be found in the specification, paragraph [0036] and Example 8, paragraph [0098]. Claims 31, 32, and 40-42 are cancelled without prejudice. New claims 43-48 are submitted. New claim 43 is substantially the same as amended claim 14, except that it recites phosphorous as the dopant. Support for this amendment may be found in claim 1 or original claim 4 and Fig. 3. Support for new dependent claims 44-48 may be found in original claims 30, 32, 33, 37, and 38. Applicants submit no new matter is added by the amendments.

Applicants express appreciation to Examiner Tran for discussing the pending Office Action on August 16, 2005. During that discussion, the photoluminescence spectrum of the material disclosed in the White reference was compared with the photoluminescence spectrum of the material disclosed in the present specification, particularly Fig. 3.

Claim Objections. The Office Action objected to claim 40 because it recites “copper oxide, antimony oxide, bismuth oxide” as p-type dopants. According to the Examiner the specification fails to provide support for p-type dopant materials that include copper oxide, antimony oxide and bismuth oxide. Applicants respectfully disagree and submit that the specification provides support for these dopants. Paragraph [0003], for example, states: “Such p-type dopants include, but are not limited to, nitrogen, phosphorus, arsenic, antimony, bismuth, copper, *chalcogenides* of the foregoing, and mixtures thereof” (emphasis added). A “chalcogenide” is a binary compound of a chalcogen with a more electropositive element. A chalcogen is any of the elements oxygen, sulfur, selenium and tellurium. Thus, chalcogenides of copper, antimony, and bismuth include copper oxide, antimony oxide, and bismuth oxide. Nevertheless, claims 40 and 41 have been cancelled without prejudice.

Claim Rejections – 35 USC § 102. Claims 1-3, 5-12, 14-22, 26-35, and 39-42 were rejected under Section 102(b) as being anticipated by White et al. (U.S. Patent No. 6,291,085,

hereinafter "White"). The independent claims have been amended to more particularly define the invention and clearly distinguish the White patent.

The White patent discloses zinc oxide films containing arsenic as a dopant. The White patent discloses electronic characteristics that would be desirable for commercially viable p-type zinc oxide. However, the White patent does not disclose actually making p-type zinc oxide. More importantly, White does not disclose how to make (or actually making) p-type zinc oxide that possesses any of the disclosed electronic characteristics (acceptor concentration, resistivity, Hall mobility, etc.). White discloses making arsenic-doped zinc oxide, but arsenic can be doped in zinc oxide without rendering the resulting material p-type.

White assumes that the mere presence of a p-type dopant requires the film to be p-type, but White does not provide any experimental evidence that proves the films are indeed p-type and possess the physical properties claimed by White. The only evidence provided by White includes the SIMS data of Fig. 3 and the photoluminescence data of Fig. 2. The White patent describes Fig. 2 at column 8, lines 55-58, as follows:

[T]he arsenic doped ZnO film of the present example shows that the acceptor-bound excitonic peak located at about 3.32 eV (3742 angstroms) is the strongest peak.

No other noticeable photoluminescent peaks are identified or discussed by White.

In contrast, Fig. 3 of the present specification discloses photoluminescent spectra for P-doped zinc oxide and As-doped zinc oxide. Phosphorous doped zinc oxide and arsenic doped zinc oxide both possess a noticeable luminescent peak at about 3.357 eV. This peak is labeled in Fig. 3 and discussed in paragraph [0081]. Both phosphorous and arsenic doped zinc oxide share a second noticeable luminescent peak at about 3.367 eV. This peak is not labeled in Fig. 3. Claims 1, 14, and new claim 43 recite that the p-type zinc oxide semiconductor material has a luminescent peak at about 3.357 eV.

The recent publication, David C. Look, "Electrical and optical properties of p-type ZnO," *Semicond. Sci. Technol.*, **20** (2005), S55-S61, reports photoluminescent properties of p-type zinc oxide and confirms that a noticeable luminescent peak is seen at about 3.367 eV for p-type zinc

oxide. A copy of this publication was submitted to the Examiner for consideration prior to the telephonic interview.

Given that the arsenic-doped zinc oxide disclosed by White lacks a photoluminescent peak at 3.367 eV, one skilled in the art may reasonably conclude that White's compound is distinctly different than the persistent p-type semiconductor materials prepared in accordance with the claimed invention. Indeed, one may even conclude that White's arsenic-doped zinc oxide material is not p-type because it lacks the photoluminescent peak characteristic of p-type zinc oxide.

As mentioned above, zinc oxide can contain a p-type dopant and not possess p-type electronic properties. The Applicants have observed this in the laboratory and identified fabrication method conditions that inhibit the formation of p-type zinc oxide. Applicants disclose limiting the oxygen partial pressure during the deposition process in the specification at paragraph [0041] as follows:

From a review of the Zn-O-As ternary diagram shown in Figures 13A and 13B, too much oxygen present may encourage the formation of undesirable ternary compounds, such as $\text{Zn}_4\text{O}_9\text{As}_2$, $\text{Zn}_3\text{O}_8\text{As}_2$, $\text{Zn}_3\text{O}_6\text{As}_2$, and ZnO_4As_2 . Hence, it is desirable to limit the oxygen partial pressure during the deposition process.

The zinc – oxygen – arsenic ternary diagram reproduced in Fig. 13A identifies several stable and neutral (not p-type) ternary compounds in the upper region of the diagram, including but not limited to, $\text{Zn}_4\text{O}_9\text{As}_2$, $\text{Zn}_2\text{O}_7\text{As}_2$, $\text{Zn}_3\text{O}_8\text{As}_2$, $\text{Zn}_3\text{O}_6\text{As}_2$, and ZnO_4As_2 . Each of these compounds has a mole ratio of Zn:O less than one. Zinc oxide, of course, has a mole ratio of Zn:O equal to one. White's fabrication process discloses ablation of polycrystalline zinc oxide in a high purity oxygen atmosphere (about 35 mTorr). Col. 8, lines 32-37. Such process conditions will lead to the formation of ternary compounds having mole ratio of Zn:O less than one, such as the stable and neutral ternary compounds identified in the upper region of the ternary diagram Fig. 13A. These compounds are not p-type.

In addition, White's fabrication process discloses annealing the film at a temperature of about 500°C for about 30 minutes. Applicants have observed in the laboratory that arsenic doped p-type zinc oxide may be converted to insulating or n-type zinc oxide when heated to

temperatures greater than 460°C. For example, Applicants disclose limiting the annealing temperature of the deposited thin film in the specification at paragraph [0046] as follows:

In some embodiments, beneficial results have been obtained when the thin film is annealed at a temperature in the range from about 300 to about 450 °C for a time period in the range from about 1 to about 15 minutes.

See also the disclosure at paragraph [0066]. Applicants submit that White's high temperature annealing step tends to destroy any persistent p-type characteristics of the material and converts it into an n-type or insulating material.

Applicants acknowledge that the pending claims are not directed to fabrication methods. However, the Examiner will appreciate that process conditions affect the resulting compound, and given that White's process is distinctly different than the processes disclosed in the present specification, one skilled in the art may conclude that the resulting compounds are different.

Because the experimental evidence provided by White suggests that White's arsenic-doped material is not "p-type," White does not "enable" one of ordinary skill in the art to prepare arsenic doped "p-type" zinc oxide. A patent claim "cannot be anticipated by a prior art reference if the allegedly anticipatory disclosures cited as prior art are not enabled." *Elan Pharm., Inc. v. Mayo Found. for Med. Educ. & Research*, 346 F.3d 1051, 1054 (Fed. Cir. 2003). Because White fails to enable the preparation of "persistent p-type group II-VI semiconductor material," Applicants submit that White fails to anticipate the invention disclosed and claimed in the instant application.

In view of the foregoing, Applicants submit that White fails to disclose each and every claim feature and element of claims 1, 14, and 43. Applicants further submit that claims 1, 14, and 43, and their dependent claims, are not anticipated by White.

Claim 27 is amended to recite that the antimony-doped p-type zinc oxide semiconductor material has a carrier mobility greater than about 100 cm²/V·s. This remarkably high mobility is discussed in the specification at paragraph [0036] and Example 8, paragraph [0098]. White does not disclose or suggest antimony-doped p-type zinc oxide possessing the claimed carrier

mobility. Therefore, Applicants respectfully submit that claim 27 and its dependent claims are not anticipated by White. Applicants respectfully request withdrawal of the claim rejections under Section 102(b).

Claim Rejections – 35 USC § 103. The Office Action rejected claims 24-25 and 37-38 under Section 103(a) as being unpatentable over White in view of Nause et al. (U.S. Patent No. 6,887,736). The Nause et al. patent was cited for the purpose of disclosing magnesium and cadmium alloys of zinc oxide. Applicants submit that the Nause et al. patent fails to disclose those claim elements and features that are lacking in White, discussed above, such as the claimed photoluminescence peak and carrier mobility. Because each and every claim element and feature is not disclosed or suggested by the combined teachings of the prior art, claims 24-25 and 37-38 would not have been obvious from the combined teachings of these patents. Applicants respectfully request withdrawal of the claim rejections under Section 103(a).

Applicants respectfully request allowance of the pending claims. If there are any remaining issues preventing allowance of the pending claims that may be clarified by telephone, the Examiner is requested to call the undersigned.

Respectfully submitted,



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